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Editor: JOHN M. COULTER

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Peat Deposits and Their Evidence of Climatic Changes
Alfred P. Dachnowski 57
(With twelve figures)

Life History of Corallina officinalis var. mediterranea - S. Yamanouchi 90

Intra-Ovarial Fruits in Carica Papaya - - - - H. F. Bergman 97
(With six figures)

Leaves of Certain Amaryllids - - - - - - - Agnes Arber 102
(With eight figures)

A Homosporous American Lepidostrobus. Contributions from the Hull Botanical Laboratory 283 - - John M. Coulter and W. J. G. Land 106

Current Literature
Book Reviews - - - - - - - - - - - - - 109
Minor Notices - - - - - - - - - - - - - 110
Notes for Students - - - - - - - - - - - - 110

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JOHN M. COULTER

With the assistance of other members of the botanical staff of the University of Chicago

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THE
BOTANICAL GAZETTE

AUGUST 1921

PEAT DEPOSITS AND THEIR EVIDENCE OF CLIMATIC CHANGES

ALFRED P. DACHNOWSKI

(WITH TWELVE FIGURES)

The time in which the various peat deposits of the United States were formed can be determined only from a joint consideration of glacial geology, climate, and plant remains. These reflect the relations between a deposit of peat materials and its environment. To attempt a correlation of this kind on a chronological basis, however, has many difficulties, which investigators in the respective sciences appreciate.

The essential nature of stratigraphic differences in peat deposits is indicated by the nature of the plant remains and the order in which layers of peat material lie upon one another, that is, by the sequence of the vegetation units which at one time formed layers of plant remains in the deposit. As to the tectonic order of the layers or series of layers of material composing a peat deposit, little need be said at this time. From the standpoint of stratigraphy the condition of the initial area in which a pioneer plant population established itself is the critical factor of greatest importance, so far as the beginning of the course of development is concerned. The sequence of the development may become changed anywhere in the course, either by changes in environmental factors or in plant population. These changes are all recorded within the deposit. In the vast majority of peat deposits the beginning of

development and the succession of peat materials have to do with the factor of water content in the original area. Usually the quantity of water is more frequently concerned than its salinity, acidity, or alkalinity. The initial water relation, by its selective action, determines not only the characters of the life forms which establish themselves as the pioneer population, but also the number of layers possible and the order of their sequence.

In a preceding paper (7) it was proposed to classify peat deposits of whatever nature into two great primary groups, the group of water-laid peat deposits and the group of land-laid peat deposits, in accordance as they have arisen in water or on partly drained but relatively moist initial areas. In the water-laid peat deposits the bottom layers consist of materials which accumulate only in standing water. They contain the remains of planktonic organisms and macerated material from plants more or less submerged or floating, or which occupied the margins of the basin. Subdivisions of this group are given in the section which follows. In the land-laid group of peat deposits the origin is indicated in the mineral substratum by the vertical roots of plants which at one time occupied the area, as a well defined plant population or vegetation unit. The general stratigraphic subdivisions in this group are indicated by the order in which the vegetation units invaded and occupied the land area. With respect to the layers of peat material formed by them the order may be (1) progressive, that is, beginning with some member of the marsh group of peat materials until the deciduous or coniferous forest climax of the region is reached; (2) stabilized, that is, it may begin and continue in a stable forest climax; or (3) the order may indicate the conversion of the basal forest climax into marsh and finally to open water conditions by the influence of various environmental causes. This distinction between the two primary groups of peat deposits is clear cut, and is readily made in field work. The only possible difficulty arises when the plant remains have been redeposited or partially removed by any later action, such as erosion. Even secondary disturbances of this nature, however, do not invalidate the importance of the stratigraphic viewpoint. Its significance for correlation studies has been sufficiently dwelt upon elsewhere (6).

The following peat deposits are representative of the subdivisions in the land-laid group, and will be reported in another paper: 1. The New Haven Marsh near Plymouth, Ohio (glacial Lake Maumee type); the peat deposit southwest of Rome, New York (glacial Lake Iroquois type); and the Algoma Muskeag near Roseau, Minnesota (glacial Lake Agassiz type). 2. The Dismal Swamp west of Norfolk, Virginia (Pamlico coastal terrace type). 3. The Kankakee Marsh, between South Bend and Crumstown, Indiana (in the Bloomington morainic system). It will be noted that peat deposits are regarded here in their relative space and time dimensions.

In regard to the stratigraphic units of peat deposits, reference may be made to Bulletin 802 (5) and left with this passing suggestion. Whatever system of classification of peat materials may be adopted, it will be found that for several reasons it cannot be carried uniformly and with constant value over so broad a territory as discussed here. The main difficulty arises from the unlike development of the vegetation unit which forms the layer of peat, and from modifications of the successional series in diverse geographic regions. Insensible gradations or phases due to variations in composition of plant remains set a limit to the most refined botanical division of peat materials that can be recognized.

Investigators approaching peat-land problems for the first time are apt to be influenced by the idea of permanence and fixity of specific limits. In a large measure this may be accounted for by the fact that the very recognition of such a thing as a type of peat material carries with it the impression of an entity, and that, if these characteristics are modified or supplanted by others, the unit in question no longer belongs to that type. The degree of individual difference admissible within a type is a matter of individual judgment. Variations exist within specific limits, but what these limits are is still a matter of diverse and constantly changing opinion, until these gradations and phases are measurably well established. No evidence of this sort of peat type limitation is available as yet, but the detailed application of ecological and instrumental methods strengthens the conviction that the

arrangement and naming of the different types of peat are merely matters of practice in field work.

In this paper it is not the intention to furnish the numerous details necessary to a knowledge of the different types of peat material, nor is it necessary to review from a voluminous European literature all the widely scattered observations on types of peat and their variations. So far as observations indicate, variations of stratigraphic units represent but a temporary condition. The structural development of a peat deposit is characterized by the regular occurrence of several types of peat material in many different forms and phases, such as differences in the growth and evolution of vegetation units. These phases are connected by more or less constant field relations. Unquestionably many so-called ecological stages represent merely fragments in the development of a peat deposit, reactions of one plant population upon another. On the other hand, well distinguished types of peat material will not only keep their position, but will receive a much more nearly complete and sharper definition than they have at present. It is for these reasons that only major divisions of plant remains are distinguished in the following discussion. They have been adopted also wherever the differences of information are sufficient to occasion difficulty in applying a uniform classification of types of peat. The list has been summarized (**5**), and has been utilized with the addition of two new marsh types of peat found in Florida and California respectively, to facilitate reference between the cross-sections of peat deposits and the text.

The conventional signs represented in the graphic illustrations of the profile sections described in large part are adjusted to the standard of European workers and the requirements of cartography. The departures which arise (partially from the inaptness of the material as a type of peat) have been stated in the legend, and in connection with each layer described in the text. Beds or strata which are not sharply defined in a deposit may be recognized by the dotted boundary lines.

It is to the interest of a group of scientific and industrial workers that coordinated efforts should be brought to the solution of peat-land problems. To those who desire general field information

regarding types of plant remains the following are some of the localities near which layers of peat material are displayed in typical form at or somewhat below the surface of the peat deposit. Macerated and colloidal types in Cedar Lake near Fremont, Indiana (fig. 2); *Phragmites* type and *Carex* type near reservoir on New Haven Marsh, Plymouth, Ohio; *Hypnum* type in Algoma Muskeag near Roseau, Minnesota, and in basal layer of the peat deposit exposed along the barge canal and James Street bridge below Rome, New York; *Cladium* type in the Florida Everglades at Okelanta and vicinity; *Scirpus* type at Middle River and near Wintersburg, California; *Sphagnum* type on Cranberry Island at Buckeye Lake, Ohio (fig. 3), and in peat deposits west of Arlberg, Minnesota; coniferous forest types near Kent, Ohio (fig. 10), and north of Kelliher and Warroad, Minnesota; mixed deciduous forest litter type in Dismal Swamp, Virginia, in basal forest of Kankakee Marsh near Crumstown and South Bend, Indiana, and in middle and upper forest beds of the peat deposit southwest of Rome, New York; deciduous forest type near Mantua, Ohio (fig. 12). More specific information concerning peat materials and their agricultural and industrial value may be obtained in Bulletin 802 (5).

I. Water-laid peat deposits.

The chief feature of the group of water-laid peat deposits is the presence of aquatic types of peat material as the initial layer. The deposits may vary widely in the number and character of the initial stages, and the number of stages may range from one layer to several in the deeper deposits, including secondary phases. From the manner in which the peat materials are laid down in standing or in flowing water, in fresh or in brackish and saline water, the successive layers as a rule furnish conclusive evidence of three major series of stratigraphic differences. The group of water-laid peat deposits may be subdivided into (1) basin deposits with standing water level, such as lake and pond deposits, and (2) deposits in depressions with fluctuating water level, the river and overflow deposits, of which the Florida Everglades and their alternation of fibrous and macerated layers of peat material are

a notable example. The coastal river and estuarine peat-lands merge into the (3) marine deposits such as tidal marsh and mangrove swamps. A discussion of the brackish and salt water deposits is reserved for a future paper.

EVIDENCE OF CLIMATIC CHANGES

It might seem that the water-laid group of peat deposits could not offer reliable and direct criteria for evaluating age or time correlations, since water in basins constitutes a fairly uniform environment. There is continuity in the sequence of strata of plant remains, but macerated and more or less structureless layers of peat material bear no fixed relation to the plant populations which succeeded each other in the development of the deposit. The organic fragments are derived from many sources, and are in large part from suspended débris. Nevertheless, inferential evidence of past vegetation units and climatic changes may occur in abundance.

The evidence for age and for climatic correlations is of several kinds, of which one form is represented in the scattering and mixing of leaves, pollen, and seeds blown into a peat deposit or washed in from adjacent land vegetation units. The latest substantial comparison between plant remains (such as the pollen of conifers) in layers of peat material and the changes in climate and in the composition of land-plant communities is the quantitative method employed by VON POST (**24**).

A second kind of evidence of climatic changes found in peat deposits consists of dark colored, partly macerated, and fibrous layers of material alternating with predominantly finely fibrous, coarsely fibrous, or woody plant remains. The close association of this kind of stratification in practically all sorts of peat deposits, without any close relation to topography or the influence of animal agencies, appears to signify alternating wet and dry environmental conditions. Quite frequently the dark colored, partly fibrous layer of peat material is referred to by American writers as "well decomposed peat." Although it bears a striking superficial resemblance to a finer texture, similar to weathered surface material, a layer of this character does not imply conditions of aeration, or of warmth

and dryness by means of which decomposition and oxidation are accomplished. The layer represents rather the open scattered growth of plant populations, such as sedges, reeds, rushes, and brown mosses. The "well decomposed" débris as a rule is the intermixture of macerated material from aquatic and amphibious plants. The presence of diatoms, sponge spicules, shells, silt, and windblown material of various kinds usually shows that the chief condition for its formation is a higher water level. So long as the water table continues at a higher level, the fibrous type of peat tends to retain the aquatic admixture; the disappearance of the macerated débris would indicate conditions of ground water below the surface soil; and an alternating sequence of these layers would mark a period of climatic pulsation, of alternating wet and dry conditions. In carrying out quantitative determinations on samples of "well or partly decomposed" peat materials, the use of the colloidal suspension test and the methods of KÖNIG (15), MELIN and ODÉN (22), and KEPPELER (13) are only partly adequate. The possibility of obtaining erroneous results must be checked by a preliminary microscopic examination of the organic material, and by a consideration of its position in the profile structure of the deposit.

Some European workers are strongly of the opinion that a climatic break in the waning portion of the glacial period is indicated by the remains of forests found buried in stratified peat deposits, and by the "horizon" layer between the lower, in part disintegrated, and the upper, relatively more recent sphagnum peat of certain high moors. The materials are believed to be evidence showing there has not been merely a steady amelioration of climate since the last ice movement, but rather a fluctuation between periods of dry and wet climatic conditions. The dissent from this interpretation on the part of other investigators does not appear to be chiefly a matter of the proper terms to apply to types of peat and their variations. These layers of "horizon" peat and of buried forest, however, constitute more properly supra-aquatic types of plant remains, and on that account their consideration is deferred to the section dealing with the general stratigraphic features of lacustrine deposits of peat. In this connection it is suggested that

superimposed layers of colloidal type of peat material in certain deposits probably indicate another kind of evidence of former relatively dry and warm climatic conditions.

A third form of evidence which may aid in the interpretation of the age of deposits and the climate which characterized their development consists in the seams of clay found between layers of peat material. These are often found with an admixture of organic matter, but rarely laminated in a manner similar to the seasonally laminated glacial clays described by DE GEER (**10**) and SAURAMO (**32**). Interstitial clay seams appear to be coincident with the earlier portion of the Wisconsin group of moraines. They have been noted especially in connection with peat deposits located in areas where readvances of the ice sheet are displayed in the drift. The investigations, however, are not sufficiently extensive to show whether the clay seams would be prominent also in morainal systems which are free from a surface cover of wind-blown loess.

The fourth form of evidence which seems very promising is that of the marked structural differences found in certain peat deposits over a wide extent of country in which a series of moraine systems is the time factor of distinction (fig. 1). LEVERETT (**19**) has shown that the Wisconsin drift displays moraines which are distinctive and well preserved. They are more or less concentrated in groups which permit of much greater detail of correlation than is possible in connection with the glacial stages in Europe (**12, 18, 27**).

The morainic systems of the Wisconsin ice sheet mark halting places in the recession of the ice front. They obviously represent climatic pulsations, for the evidence seems clear that the ice sheet was subject to increase or decrease in response to climatic variations. Periods of warmth during which the ice sheet retreated somewhat rapidly, leaving nearly level tracts of drift, must have alternated with periods in which the climate ceased to be mild, and either remained nearly uniformly colder for a time or else reverted toward the conditions which induce glaciation.

For the study of past climatic changes and plant migration since the culmination of the last stage of glaciation, a comparison of the stratigraphic features of peat deposits should bring out evidence of great value. By actual test borings of peat deposits

within the area of the several great morainic systems, such as the Shelbyville, the Bloomington, the Valparaiso-Kalamazoo-Mississinawa, the Lake Border–Defiance, and the Port Huron, it should

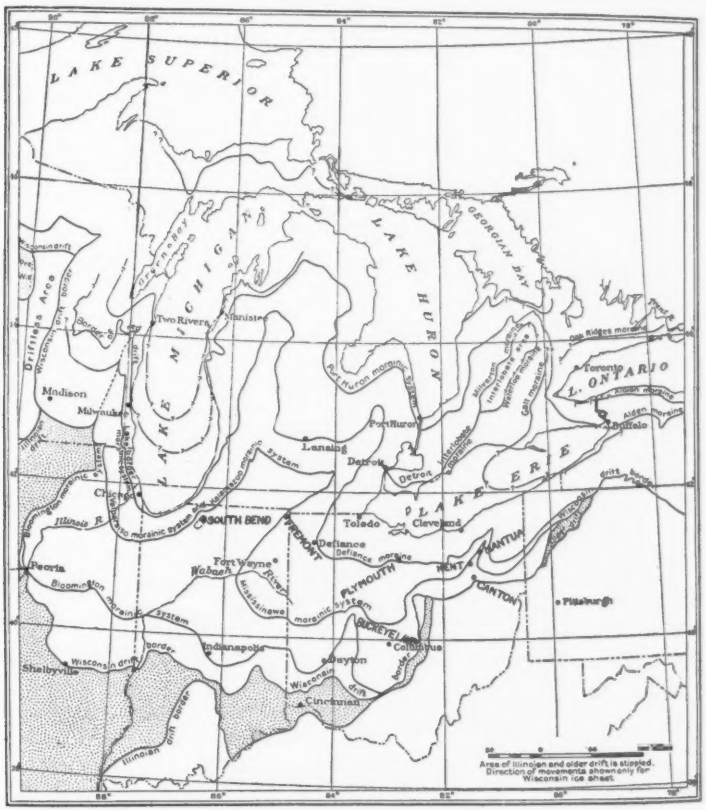

FIG. 1.—Diagrammatic outline of Wisconsin ice border at several successive positions (after LEVERETT and TAYLOR 19 with slight modification): lines of direction of ice movement omitted from original map, and names of a few localities with peat deposits added by writer.

be possible to sum up the whole series of climatic changes which have taken place while the ice field receded, and to estimate the length of time for every single glacial substage. Primarily because

of their greater age, the deposits of the earlier morainic fields constitute climatic indicators of the greatest interest, and they should not only furnish additional data, but also serve as a check upon any evidence which the peat deposits in the later morainic areas may contribute.

The material here presented is only of preliminary import. It has emerged in the field work of the past seven years, and hence a definite correlation is impossible as yet, partly because too little is known of the extent and intensity of the changes. The chief difficulty, however, lies in the fact that much along the line of detailed field and laboratory studies has still to be accumulated. The conclusion is irresistible, however, that when the field is traversed the peat deposits will be found to furnish a new great record of the vegetational and climatic history of the country since Pleistocene times.

General stratigraphic features in water-laid peat deposits

The question of the formation of lacustrine peat deposits has produced a copious literature in many countries, but there is still a dearth of observational evidence on their actual structural origin. Hardly a case exists of an intensive study in which conclusive proof is available showing the types of peat material in process of formation. This does not mean that the process may not be as is generally assumed, but it does indicate that even a well-nigh universal opinion may yet constitute merely an excellent working hypothesis. It can be accepted definitely only after more rigorous tests and extensive field work disclose a clearly defined basis. This account merely serves to emphasize what may be regarded as a general view of the development and structure of lacustrine peat deposits. Although this has been discussed at some length in various papers already published, a brief outline is presented here in order to connect it with the profile sections of the peat deposits on which these discussions have a bearing. The cross-sections which follow have been selected from American and European peat deposits largely on account of their stratigraphic relationship. They visualize the succession of strata in water-laid deposits, and illus-

trate the general development which had come to the final stage possible under the limits of the particular field conditions of different countries.

In a consideration of basined deposits or moors it should be kept in mind that depressions with standing water originate in a great variety of ways (30). Of chief importance, however, is the fact that the initial types of peat material are primarily water-laid. They are largely confined to the lower or deeper parts of the depression, where planktonic organisms, together with comminuted fragments and other plant remains from both land and aquatic vegetation, sink to the bottom. A complete filling of lake and pond basins does not usually occur by the formation of aquatic types of peat material. The peat-land near Fremont, Indiana (fig. 2), represents a relatively rare deposit of peat. The level where the higher plant communities can gain a foothold or succeed one another depends upon the ability of the plants to form a

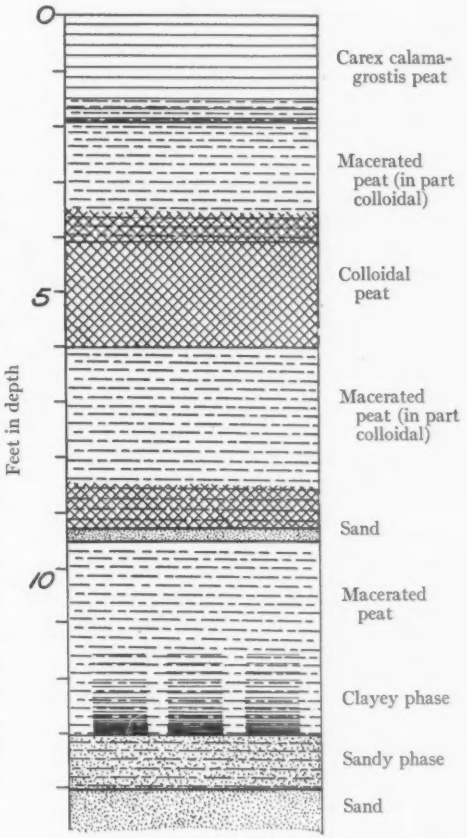

FIG. 2.—Cross-section of soundings in "Cedar Lake" peat deposit near Fremont, Steuben County, Indiana.

floating mat. The thickness of purely allochthonous (transported to the place of occurrence) layers of peat, therefore, is far less extensive than might be assumed, partly also because submerged and amphibious plant populations can take root in depths varying from 10 to 15 feet (3–4.5 m.) and accumulate as peat in situ. The macerated type of peat is nevertheless preeminent, and it varies least in character under conditions which give rise to water colored brown from the presence of suspended and dissolved organic débris. On account of the decrease in light and heat available, and the consequent absence of submersed plant communities, the filling of the depression is chiefly from vegetation units bordering the basin. The colloidal and doppleritic types of peat, on the other hand, make clear another set of conditions; they appear to indicate a higher calcium carbonate content of the waters at the time of their formation, and stimulating environmental conditions of temperature and light, in which the growth of aquatic vegetation units and planktonic organisms probably reached unprecedented proportions. There are reasons for concluding that the colloidal and doppleritic types of peat may represent another kind of evidence of climatic fluctuations. In the deposit near Fremont, Indiana (fig. 2), for example, colloidal material alternates with layers of macerated and "acidic" plant remains. The formation of colloidal material, therefore, may correspond in time with conditions of drought, when the lake or pond waters were concentrated by evaporation and became alkaline as concentration progressed. It is quite probable that the finer calcareous material in the drift had been removed by leaching, and produced variations in the chemical composition of the lake and ground waters. The calcium carbonate content when separating in the open water in a finely divided state must have become mingled with the plant débris so as to form a flocculation product and in places an end product of plant disintegration combined with lime. The climatic changes which brought about this condition may not have been sudden or excessive, but probably were oscillations of moderate intensity, whose cumulative effects were felt during that period of time.

The rate of building up a peat deposit in lakes or ponds appears to increase considerably as a plant population such as that formed by sedges pushes out from the shores, becomes nearly or quite

closed and exclusive, and forms a floating mat. Essentially this mat is fibrous and contains macerated débris. When only partially attached at the sides or beneath the surface, and if for any cause there is a considerable rise of the water surface, the mat floats upon a pocket of water (fig. 3). Later the mat is compact enough to bear the weight of shrubs, trees, and even of dense forests. When, however, the weight of the floating mat becomes too great, it either breaks or sinks with its load. Layers of marsh, shrub, or forest types of peat material then occur, interpolated between layers of aquatic plant remains. Thus an inverted order of superposition results. It would obviously be a fallacy to correlate stratification of this kind with alternating dry and wet climatic periods. Neither would the profile indicate conversion such as may result from artificial causes which obstruct drainage, nor a backward sequence of plant communities, that is, retrogression.

It is apparent also that in the gradual closing of basined

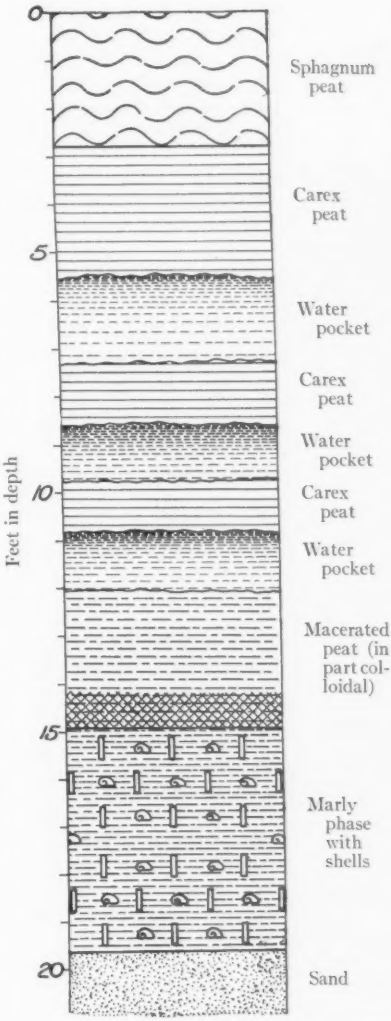

FIG. 3.—Profile section of "Cranberry Island" peat deposit at Buckeye Lake, Licking County, Ohio: elevation 892 feet a.t.; location of sounding near former experiment station (see fig. 4, BOT. GAZ. 52: 25. 1911); a dike was built in 1838 which raised the water level 8 feet.

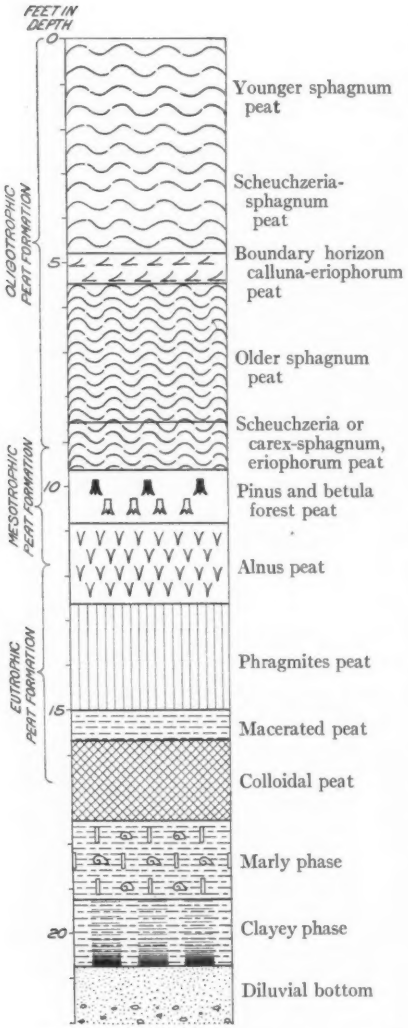

FIG. 4.—Generalized section through North German peat deposit 7 m. (22 feet) in thickness, showing succession of layers of peat material; after WEBER (36).

water by vegetation units there is not only a gradual decrease in available ground water, but in mineral food constituents as well. The earlier plant communities and those which occupy a position near the margin of the basin derive their salts from the water or from the soil on which they grow. For the succeeding units this becomes less and less in amount. When completely filled, the inward sequence of peat material (the horizontal section) and the upward sequence or vertical section of plant remains may show characteristics successively distinct in content of mineral matter, such as lime, and of water incident to the increase of thickness of peat. The difference between the total mineral content of a peat deposit and an adjoining lake has been shown for Cranberry Island at Buckeye Lake, Ohio (3). The term eutrophic is used by WEBER (36) for types of peat formed in water rich in mineral nutrients, and oligotrophic

for types with water poor in saline food constituents, while mesotrophic is applied to the peat materials in the intermediate stage (fig. 4).

Another significant difference lies in the fact that the final climatic vegetation unit of a particular region, for example, a deciduous forest (fig. 12) or a coniferous forest, is also the climax stage of the sequence of peat materials in lacustrine deposits. Successionally the sphagnum and heath shrub vegetation units appear to be a later stage in the structural development of peat deposits. Their superposition upon marsh or forest types of plant remains, however, is not to be considered an anomaly or an exception. The sequence stands in the same causal relation to development as is the case with other vegetation units. Here, however, it is connected with the fact that the ground waters of peat deposits in this stage of development are deficient in mineral salts, and that bog mosses absorb and retain large quantities of rain water on account of their anatomical structure. Sphagnum peat materials reach their greatest thickness in cool humid locations with abundant rainfall, and contain as a rule only little mineral matter. Theoretically the sphagnum stage in the structural development of a peat deposit should be succeeded by shrub, and finally by forest stages in the course of time. Actually this does not appear to take place, unless the layer of moss peat has been reduced in volume by disintegrating processes, and as a result becomes more permeable to ground waters. In the present state of our knowledge it is impossible to be certain that disintegration can occur without a change in climate. Thus the "horizon peat" between the lower (older) and the relatively more recent (upper) sphagnum peat in northern Germany (fig. 4) is regarded by WEBER (**36**) as due to a climatic change unfavorable for the growth of sphagnum mosses. VON POST (**23**) has corroborated this view by his work in Sweden, VAN BAREN (**1**) confirmed it for some of the peat deposits of the Netherlands, and ZAILER (**37**) verified it for the peat deposits of the Enns Valley in the Austrian Alps. The layer is assumed to indicate a long interruption of peat formation, during which the high moor was covered with *Eriophorum* and *Calluna*, and sometimes with forest. WEBER and VON POST conclude that the horizon peat

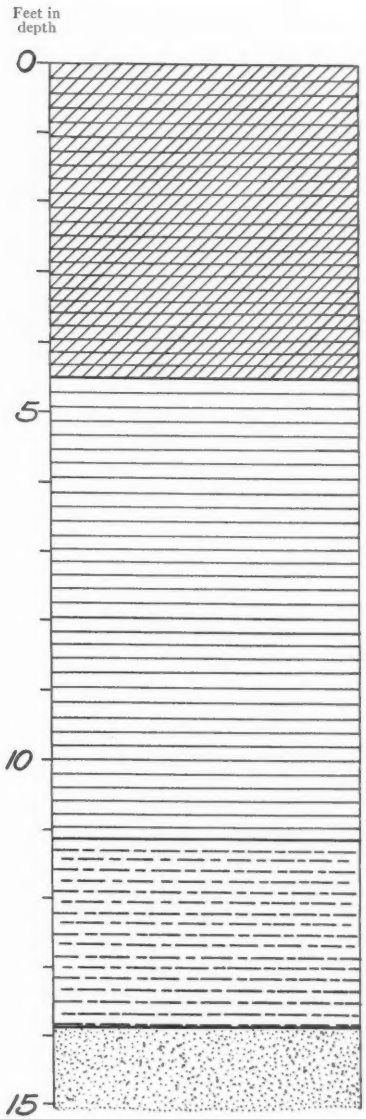

FIG. 5.—Cross-section of peat deposit near Sarna Station, Volinsk Province, Russia; after DOCTUROWSKI (**8**).

must have been built about the end of the later Stone Age and after the *Litorina* subsidence (**33**, **34**). On the other hand, RAMANN (**28**) and POTONIÉ (**25**) concluded that the assumption of a change of climate is unnecessary, and that the horizon layer is determined by the physical characteristics of this type of peat. The double character of the sphagnum layer is accounted for by the gradual diminution of the water raised by capillarity during dry seasons in certain thicknesses of the peat material. "Die Sphagneen können dann nicht mehr aus den tieferen Schichten mit Wasser versorgt werden und sind auf jene Mengen angewiesen, die sie in ihrer wachsenden Schicht festzuhalten vermögen. Es werden dann zwei wasserreiche Lagen vorhanden sein, eine tiefliegende und die

Oberschicht, beide durch trockneren Torf getrennt." LESQUEREUX (16) also believed that peat deposits when checked by dryness form a parting layer between an old and a new bed of peat which takes on the shape of a dry layer.

With increasing study of the structural features of American peat deposits, correlations of various kinds will undoubtedly demand more consideration and will assume their basic importance. At present, however, it appears to be well founded to regard apparent structural climax layers as depending mainly upon the continuation of certain regional field conditions. It has already been suggested that the structural development of a peat deposit may fail to terminate on account of unfavorable local field conditions, and that various factors may inhibit a further development or may produce secondary stratigraphic features of varying character. There appears to be little doubt, however, that whenever

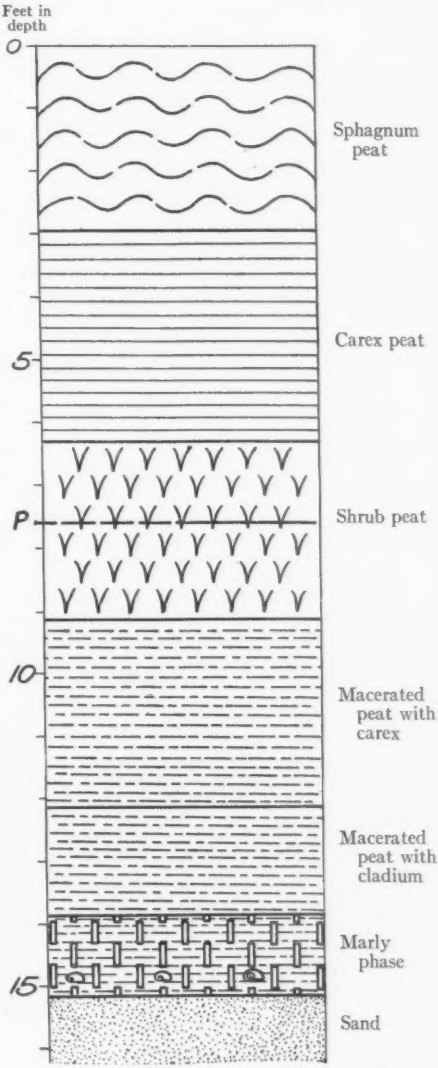

FIG. 6.—Profile section of the Åsle peat deposit, Hornborgasjön, Sweden; after SANDEGREN (31).

the movement of plant populations continues, either through a further change in habitat or in the development of new plant communities, the climatic vegetation unit is also the climax in the stratigraphic sequence of peat materials (figs. 5–7).

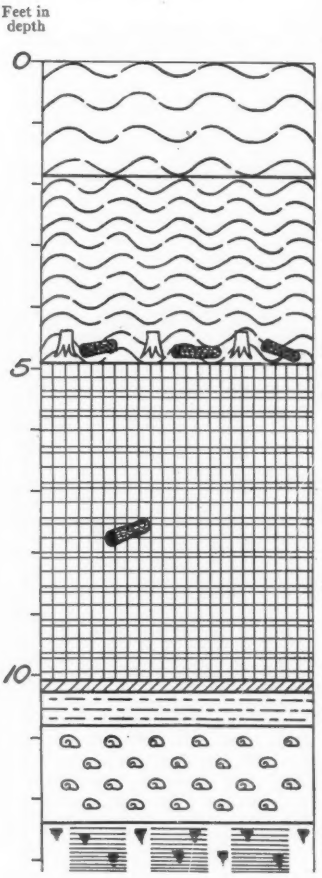

FIG. 7.—Generalized section of peat deposit of Lonsdale lacustrine moors, England; after RANKIN (29).

EVIDENCE OF CLIMATIC CHANGES IN OHIO

Peat investigations are still an unspecialized field in which the interrelation of climate, geology, and vegetation plays the paramount rôle. Whether in the service of science or of agriculture and other industries, the peat-land problem comprehends all the complex correlations of plants and their habitat; hence it should also furnish a historical perspective and the points of departure which lead to past relations. It would be presumptuous at this time to attempt to draw a parallel between the climatic changes recorded in the different peat deposits of this country. A reciprocal relation can scarcely be discovered, even in a general way, from only the few and incomplete records, and yet, although tentative, a short statement descriptive of the preliminary results obtained

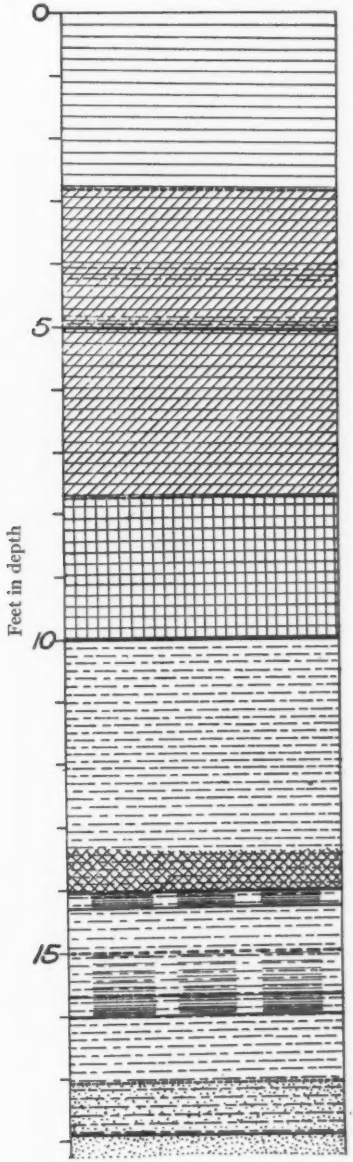

FIG. 8.—Section of peat deposit showing layers of peat material in deposit at Canton, Stark County, Ohio; elevation 1104 feet a.t.; sounding taken 300 feet south of 12th str., N.W., west side of N.O.T. car line.

may be of interest. A full correlation can be reached only by repeated efforts of this kind. Emphasis will necessarily fall upon glacial formations, because they are both an effect of climatic fluctuations and a cause in the age relation of peat deposits. The general microscopic analysis of the plant remains is reserved for a more comprehensive paper to follow.

With regard to the order of age, from older to younger, it is advantageous to compare briefly a few peat deposits (figs. 8, 10, 12) located between Canton and Cleveland, Ohio. In this part of Ohio several of the great morainic systems of the Wisconsin stage of glaciation are closely crowded together. They extend from Canton northward as a massive (interlobate) belt, and show nearly all the advantages of individual distinction

without involving the complications which occur in the broader intermorainic tracts as a result of subsequent changes in drainage. The general physical features of this area have already been described (**4**). An extended account and delineation of the geology and soils has been given by LEVERETT (**17**) and in the field operations of the United States Bureau of Soils (**20, 21**). A diagrammatic representation of the successive positions of the ice border and the location of the peat deposits is given in fig. 1.

The Canton peat deposit (fig. 8), like the Buckeye Lake deposit (fig. 3) farther southwest, is among the first and the oldest in Ohio. In both the basal layers of macerated plant remains represent accumulations of peat which probably began while the ice border was receding from its maximum position across Illinois, Indiana, and Ohio to about the limits of the Bloomington group of moraines. The growth of peat-forming vegetation in these two deposits followed soon after the recession of the ice sheet, before the drift had become drained by development of valleys on it.

Two seams of clay in the Canton deposit are noteworthy. Their positions indicate that the early period of peat formation was at least twice marked by climatic disturbances. The presence of the two layers of clay between layers of macerated types of peat seems to show that the ice readvanced to near this point into territory that had been laid bare following the maximum extension of the glaciers. In these states the western end of the Bloomington group of moraines not only overrides the weaker ridges of the Champaign moraines, but also extends into the ground occupied by the Shelbyville morainic system which was formed at the culmination of the Wisconsin stage of glaciation. The clay was probably deposited along the border of the ice mass by the same agencies that contributed the coarser material at the margin of the moraine, while further out, in the water basins, sand and finally clay were left. The deposition of clay may have taken place chiefly during the retreat of the ice front, when climatic conditions had become much warmer. It is not improbable that these clay seams represent the loess material which is known to cap the earlier morainic systems of the Wisconsin drift. Much of the material from the loess covered plains may have been carried

up by strong winds, forming at first a surface coating upon the ice at the time the moraines were developing. The effect of possible meteorological changes over wide areas, such as PENCK and others have worked out, must be borne in mind. The shifting of all climatic zones southward (**26**), caused by the general lowering of the temperature during the Ice Age and the depression of sea-level, points to the probability of this area as part of a relatively windy arid belt. After the ice had melted back some distance, the inorganic material may thus have come to be contributed to the peat deposit.

The basal layer of macerated peat is somewhat silty, and has a rather aged appearance. It is assumed, provisionally, to have been formed during the first or Shelbyville period of deglaciation. The layer of plant remains found overlying the basal peat has a much fresher aspect, but the organic débris in both of the lower layers of peat seems to fall short of reaching the greater variety of plant fragments which occurs in the succeeding layers. Further study of a microscopic nature, however, is necessary to establish fully the character of the plant remains from each of these glacial substages. The strongest evidence of an interval between the formation of the basal macerated peat and of the overlying layer of macerated plant remains is found perhaps in a comparison of the character and amount of the uppermost seam of clay. This clay seam is much more sharply terminated than the lower one, and it is also worth noting that the upper thickness of the clay stratum is compact and relatively free from plant remains. Whether or not the evidence thus far at hand favors the view that the seam of clay is derived from wind blown loess rather than from drift, or differences in the strength of the outwash, of considerably greater significance is the fact that the upper mineral layer constitutes a distinct break in peat formation. The cause of this break in the succession of peat materials must evidently have been a change from colder climatic conditions, from a more or less notable readvance, and a renewed aggression of the ice sheet.

Apparently the climate was undergoing amelioration at the time, probably giving rise also to a lower water table. That such oscillations have occurred is evident from the work of LEVERETT

and others. A certain degree of aridity seems to have prevailed, not only during the withdrawal of the ice, but up to the period which resulted in the formation of the Bloomington morainic system. The Bloomington period of peat formation was stopped by the upper seam of clay. This suggested correlation appears to be correct, for the upper clay layer can be connected closely with that part of the Valparaiso-Kalamazoo-Mississinawa morainic system which passes northeast of Canton through Portage County. The principle members of this group of moraines show west of here a marked differentiation of glacial lobes and a shifting of the lines of axial ice movements. The glaciers, as shown by the studies particularly of LEVERETT and others, encroached again over the surface of land that had been vacated by the earlier recession of the ice border. This readvance, the limits of which are marked by a morainal belt reaching from eastern Illinois and extending northward into Michigan to the vicinity of Kalamazoo and Battle Creek, has usually been designated the late Wisconsin stage. It covers a time of drift deposition reaching to the series of generally weak moraines which are included in the Lake Border-Defiance system.

During the time which elapsed while this ice front receded, and which may tentatively be called the Mississinawa glacial substage, the third tier of macerated peat was formed and probably also some of the superposed layers of fibrous plant remains. There is hardly any feature in the structure of the Canton deposit so conspicuous as the fibrous layers of peat, which rest on and in places grade into the underlying third basal bed of macerated organic material. The *Carex* and *Phragmites* plant populations, from which these layers of relatively coarse fibrous peat are derived, appear to have grown at ground water levels much lower than those which prevailed at later glacial substages. The uppermost beds of fibrous peat of more recent development contain an admixture of aquatic plant débris. They do not represent in their texture the features which would be characteristic of a gradual decrease in available ground water coincident with the closing of water basins by vegetation.

In the absence of more definite correlations, these three primary series of peat layers, namely, the several basal layers of macerated plant remains, the middle bed of coarsely fibrous peat, and the

upper layers of partly fibrous plant components, might be interpreted as representing three great changes in water level. They

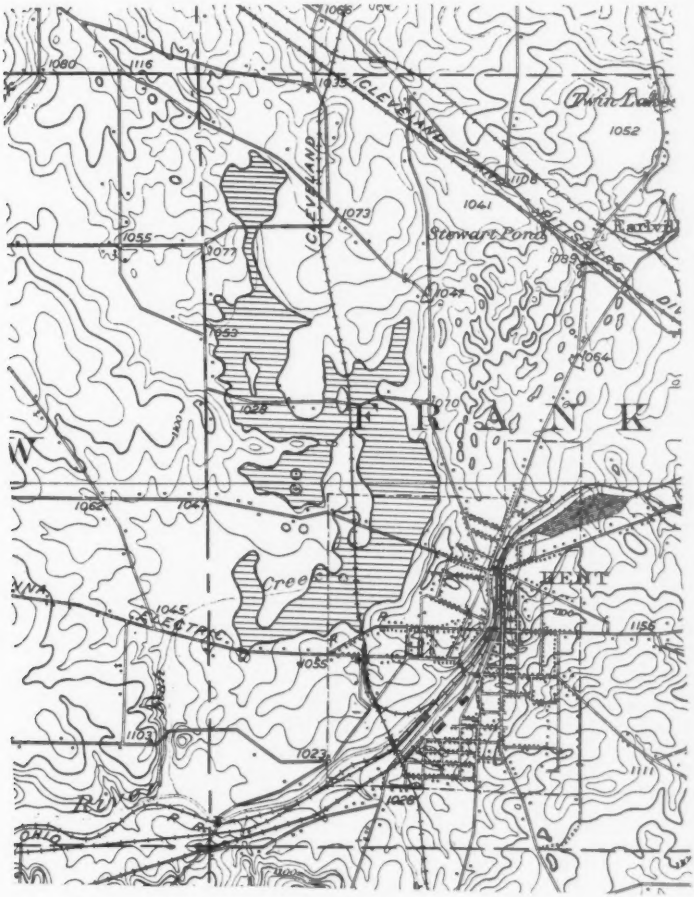

FIG. 9.—Location of peat deposit near Kent, Portage County, Ohio, and of sounding illustrated in fig. 10; scale, 1 inch = 1 mile (2.5 cm. = 1.6 km.).

may correspond, therefore, to three climatic stages that left their traces in the structure of the Canton deposit. From this it would seem that a comparatively warm period with moderately humid

conditions must have been preceded and followed by two comparatively cool periods, characterized by changes between drought and wetness greater in degree than seasonal variations. For this interpretation, however, a series of various facts is doubtless required. A consideration of the structural appearance of the deposits in line north of Canton should give more adequate evidence of such alterations. They represent in part a contemporaneous and later age of peat formation which should bring into clearer perspective the probable climatic conditions during and after the close of the third glacial substage.

The recession of the ice front marked by the Valparaiso-Kalamazoo-Mississinawa morainic system to near the border of the Huron and Erie basins initiated the development of the Kent (fig. 10) and the Mantua peat deposits (fig. 12) in the order named. An examination of the profile sections suggests a long interval of peat accumulation. In about the middle of the Kent deposit there is evidence that here also an unusual disturbance had affected the course of peat formation, and that a well marked climatic change had occurred. The position of the layer of forest peat in the Kent deposit suggests that the change is contemporaneous with the deposition of the Lake Border-Defiance system.

At the bottom of the Kent deposit, overlying the bowlder clay, are shells of fresh water mollusks, and above them a layer of plant remains from aquatic vegetation. This is followed by macerated material, a part of which is distinctly gelatinous. The upper portion of the structureless débris merges into a layer of fibrous plant remains, showing that a mat of sedges and other marsh plants had covered the basin. When this stratum was formed, a mixed deciduous but predominantly coniferous forest appears to have been growing on the borders of the basin, which gradually encroached and finally occupied the entire peat-land area. The thickness of the layer of forest litter shows that the ground water level at that time was below the surface soil, and that the tract remained moderately moist for a considerable period of time.

It can scarcely be decided in the present state of investigation whether or not the end of the Mississinawa glacial substage was accompanied by a widespread dispersal of forest trees from south-

eastern portions of the United States. The first coarsely fibrous layers of *Carex-Phragmites* peat in the Canton deposit, and especially the middle forest bed of the Kent deposit, certainly have a suggestive feature of resemblance. Among land-laid peat deposits, the basal forest bed in the Kankakee Marsh near South Bend, Indiana, appears to indicate a corresponding time relationship, the climatic conditions of which favored forest associations more distinctly southern in range. Layers of coarse, fibrous peat material and of forest peat seem to offer the evidence of a prolonged warm period, during which migration of deciduous shrub and forest vegetation units might readily have taken place to areas considerably more northward than they are at the present time (14). From these facts there appears some support for the suggestion that the probable range in temperature and precipitation as well as the duration of this warm period made it possible for many trees

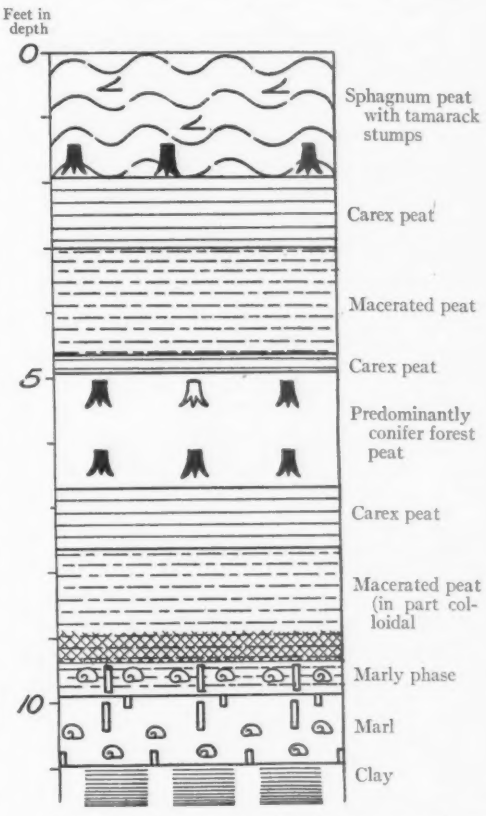

FIG. 10.—Cross-section showing structure of peat deposit near Kent, Portage County, Ohio; elevation 1028 feet a.t.; location of sounding indicated on map (fig. 9).

and shrubs to extend rapidly the limits of their distribution. It is unwise, however, to venture more, since at the present time definite stratigraphic and botanical data from peat deposits of northern states have not been exhaustively studied, nor have the investigations of the later quaternary deposits of the eastern and southern coastal states been carried to a point where they could be definitely correlated with the peat beds of this glacial substage.

There followed a wet period, during which the forest in the Kent deposit seems to have become submerged. The weight of the trees can scarcely have caused a sinking of the forest layer in this basin, since its depth is small and the underlying layers of peat material show no compression or disturbance. With the rise of the water table a layer of fibrous material from sedges and various other marsh plants began to accumulate above the forest stratum, but there soon followed a more rapid increase in the water level. The area became covered for a time with water.

The period of change recorded so conspicuously in the Kent deposit appears to be associated with the Lake Border glacial substage. It is readily correlated with the time which elapsed when the front of the Erie lobe receded northward to the Port Huron morainic system. As the ice in its retreat uncovered the Ohio divide, inundation followed the escape of waters from the subsequent melting of the ice masses. No clay, however, entered into the formation of the peat deposit. The Lake Border moraines are practically free from loesslike silts, and apparently they were not strong enough to spread a seam of clay over this basin. When peat accumulation recommenced, there was again formed a layer of macerated material, followed by a fibrous type of peat from sedges, above which appears a stratum showing small twigs and branches of shrubs. Once more the area had become cool and dry, too severe perhaps for the free spreading of forests. Probably many tree species were again driven southward and replaced by more open vegetation, such as grassy marsh and shrubs. This cool period meliorated in severity rather rapidly and became sufficiently temperate for forests, for in the uppermost layer of peat are the remains of tamarack (*Larix* sp.). The stumps of the trees are standing in the peat itself. The present surface vegetation is a dense stand

of tamarack. In the partially wooded portion grow heaths such as *Cassandra* (*Chamaedaphne*) sp., *Vaccinium corymbosum*, and others, while the ground cover consists largely of sphagnum mosses with the cranberry and similar plants characteristic of sphagnum bogs. The southern portion of this tract is under cultivation.

Turning to the Canton peat deposit, it is interesting to note that the middle forest layer is wanting in this deep basin. The type of peat material of the period contemporaneous with the Kent middle forest layer consists of fibrous and relatively coarse plant remains from sedges and to some extent from reeds. The quantity of water must have diminished independently of the local alterations in the water table, for layers of a fibrous texture accumulate only under moderately moist conditions. The overlying peat stratum, on the other hand, is formed from *Hypnum* mosses and sedges, and has an admixture of macerated débris, clearly showing the advent of a cool period.

The succeeding layers in the Canton deposit show a gradual elimination of the *Hypnum* mosses as a peat forming component, and they also indicate a return of atmospheric conditions swinging toward a warmer climate. Before its cultivation the Canton area is reported to have been a marsh with the margins partly forested. Thus the uppermost layers of peat in the two deposits seem to show that during their later history, from the last glacial substage (the Port Huron time and the Lake Champlain period) to the present, the amelioration of climate has been relatively more steady than at any time since the culmination of the Wisconsin period. The lack of structural diversity is related probably to the distance of these deposits from the direct influence of the later glacial substages.

The beginning of the Mantua peat deposit (fig. 12), it is reasonable to infer, dates from the period of accumulation of *Hypnum* mosses in the Canton peat deposit and the submergence of the forest layer in the Kent deposit. In the Mantua deposit the uppermost layers similarly point to the supplanting of a cool by a more temperate period of climatic conditions, and to the migration of plants as an essential process in the sequence of peat materials. It is worth noting that the forest layer has the stumps of tamarack

(*Larix* sp.) in the lower portion of the stratum; while those of maple (*Acer* sp.), ash (*Fraxinus* sp.), and elm (*Ulmus* sp.) are found in the forest litter nearer the surface. The degree of natural drainage which established itself in time on the surface layers of this deposit determined, probably in large part, the character of the succeeding vegetation cover. Deciduous trees such as the red

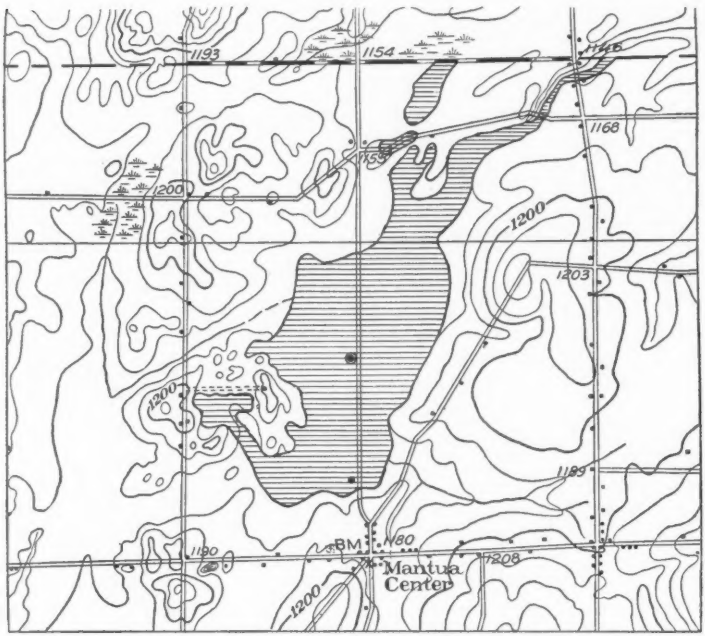

FIG. 11.—Location of peat deposit near Mantua, Portage County, Ohio, and of sounding on lot no. 9 illustrated in fig. 12; scale, 1 inch = 1 mile (2.5 cm. = 1.6 km.).

maple, black ash, and elm are still the dominant trees in the present surface vegetation of this tract of peat-land. Here again it is obvious that much is not yet clear about the major changes of climate until quite recent times, and that more extended and more critical field studies are required upon northern deposits which admit of ready comparison with the older peat accumulations. These questions of climatic changes from the later glacial sub-

stages to the present are critically important, for they bear radically on interpretations that have already been well supported in the countries of northern Europe.

It does not lie within the sphere of this paper to review the literature dealing with the probable causes which produced the glacial period or its climatic changes. These and other considerations are discussed fully by CLEMENTS (3), DOUGLASS (9), HUNTINGTON (11), and others. The only question is how far the types of peat material and their sequence in peat deposits may furnish evidence of climatic effects during the successively less extensive positions of the ice border. The facts given in this article seem to indicate at least three if not four major oscillations during which the climate fluctuated between warm and cold conditions, between periods of greater dryness and greater humidity.

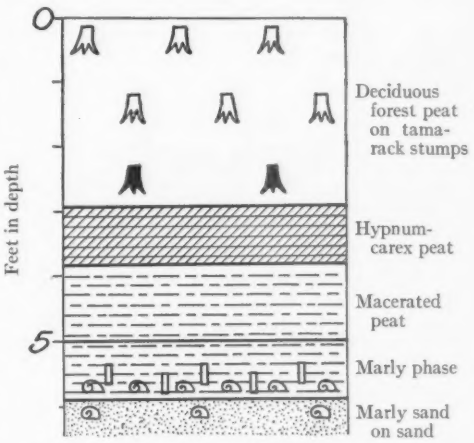

FIG. 12.—Profile section showing sequence of strata in peat deposit near Mantua, Portage County, Ohio; elevation 1155 feet a.t.; sounding on lot no. 9, west side of Center Road, as indicated on map (fig. 11).

Summarizing the climatic changes since the disappearance of the Wisconsin ice sheet in Ohio, the following may be stated tentatively: In the record of a few Ohio peat deposits an irregular series of changes can be traced, due to effects of climatic influences. Apparently twice a comparatively dry and cool period alternated with a relatively warm and humid period. After glaciation had reached its maximum extension, there followed two minor periods of recession of the ice field, a time during which a cool and dry climate bordered closely the glacial regions in this locality.

It was probably a period of winds, cooled from the ice sheet, and of loess deposition. The accumulation of drifted, wind-blown sand in the Kankakee, Indiana, area, portions of which were later covered by peat materials from a basal forest, may be referable to the first two glacial substages. In the general shifting of climatic belts the cold climate along the border of the retreating ice probably passed into dry windy conditions. On the exposed ground-till only marsh plants and low shrubs may have been the dominant plant population. This period of relative aridity in turn gave place to a second great advance of ice, the late Wisconsin, probably not of as great severity as the first, after which a prolonged warm and somewhat humid climate prevailed. This appears to have been the period of invasion and wide dispersal of forest trees from the south, and of a more northerly distribution of certain species than is now recorded for them. As to the end of the late glacial time, the climatic characteristics from the last glacial recessions to post glacial and present conditions stand as yet considerably ill defined. The evidences indicate periods during which the climatic zones shifted again somewhat. There appears to have been a return to cooler and drier climatic conditions, followed by a temperate and more humid period than exists at the present time in the same localities. The present period is probably approaching a climate of rising temperatures and (or) decreasing precipitation. The botanical data, however, are as yet insufficient to permit more definite conclusions, and they are wholly inadequate for drawing a parallel between the past climatic conditions of different countries.

The writer has had considerable hesitation in publishing the climatic correlations for the peat deposits of these great morainic systems. Although the interpretation accounts for a series of facts that are in need of being formulated, yet there might perhaps be another way of correlating the field observations. For this, however, the work of several years will doubtless be required. This preliminary paper may aid in the meantime a field of peat investigations to which BLYTT (2), WEBER (35), and others have been among the first contributors. With these major climatic fluctuations as a basis, chronological data of considerable value may perhaps be obtained by this method of peat investigations

for several sciences, including archaeological research. In its relation to the practical worker in peat-land problems it is hoped this paper will suggest the influence which structural differences in peat deposits necessarily exert upon a true estimate of the value of peat deposits and upon the progress of peat-land utilization, especially upon the plans, methods, and equipment which must be adopted to convert suitable areas into productive sources of national wealth.

UNITED STATES DEPARTMENT OF AGRICULTURE

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LIFE HISTORY OF CORALLINA OFFICINALIS VAR. MEDITERRANEA[1]

S. YAMANOUCHI

The group of red seaweeds known as the Cryptonemiales includes many species displaying a wide variety of form. The structure of the reproductive organs and the mode of reproduction found in this group cannot be ascertained adequately by the study of a single species. In order to distinguish the Cryptonemiales from the other groups of Florideae, the method of reproduction, as existing in *Dudresnaya*, has constantly been cited as characteristic and representative of the entire group; but it is merely characteristic of that genus. Moreover, our present knowledge of *Dudresnaya* is confined to its morphological features. In any systematic arrangement of the forms belonging to the ill-defined Cryptonemiales, *Corallina* should always be placed near the summit. This does not mean, however, that the structure of the reproductive organs and the mode of reproduction are more complicated than in other forms belonging to this group. About 30 years ago, SOLMS-LAUBACH published his original work on the structure of *Corallina*, but no cytological work was attempted, and the life history of the plant was not established. Consequently, a cytological study of *Corallina* was made from material secured at the Bay of Naples, Italy.

Origin of conceptacle

Generally the conceptacles are formed at the ends of branches of the thallus. The reproductive organs, which arise within the conceptacles, originate from these so-called disk cells which compose the central portion of the growing apex of each branch. The disk cells located at the periphery continue to divide and grow up around the reproductive organs, leaving only a small aperture or ostiole at the apex, thus forming the conceptacle. The three kinds

[1] Translated by CLARENCE C. BAUSMAN, assisted by C. CHIBA, from Bot. Mag. Tokyo **27**:279–285. *figs. 1–8.* 1913.

of reproductive organs (antheridia, carpogonia, and tetraspores) are produced in conceptacles on three different individuals.

Nuclear division in vegetative cells

Nuclear division is very common among any of the vegetative cells, but is most conspicuous among the actively growing (disk) cells at the ends of the branches. The cell structure varies more or less according to the position of the cell, but as a rule the nucleus occupies the central portion of the cell. One or sometimes two large vacuoles are present, and also many chromatophores. The cytoplasm seems to be distinctly alveolar in structure. The nucleus in the resting condition contains one and sometimes three or four irregular nucleoli. The chromatin material, during the resting condition of the nucleus, consists of small granules scattered throughout the karyolymph. Upon approaching the period of nuclear division, the nucleus slightly enlarges, and the chromatin, which up to this time was in the form of granules, increases in amount and finally becomes organized into a definite number of chromosomes. The male and female individuals possess twenty-four chromosomes, while the tetrasporic individuals have forty-eight. The contents of the nucleolus gradually become decreased with the formation of the chromosomes, and when the chromosomes have arranged themselves in an equatorial plate, the nucleolus has completely disappeared.

In the prophase a small, granular, centrosome-like body makes its appearance at each of the two poles of the nucleus in the cytoplasm near the nuclear membrane. Within the nucleus spindle fibers are soon formed, originating from the centrosome-like body. The alveoli of the cytoplasm immediately surrounding this centrosome-like body form branched astral rays. In later prophase the centrosome-like body becomes enlarged, and thus the centrosphere is produced.

In the metaphase the chromosomes divide, and when the two groups of daughter chromosomes reach the opposite poles, the daughter nuclei are soon formed. Up to and including the formation of the daughter nuclei, the centrosome-like body retains its characteristic form. With further growth of the daughter nuclei,

however, it gradually decreases in size, and at the approach of the resting stage of the nuclei it becomes unrecognizable. With the return of the period of nuclear division, the centrosome-like bodies reappear, as just described, at the opposite poles of the nucleus.

SWINGLE and others who studied *Sphacelaria* and *Stypocaulon* maintain that the centrosome or "central body" persists from one mitosis to another. HARPER appears to be of the same opinion, as a result of his work on *Lachnea* and *Phyllactinia*. As regards *Corallina*, the two centrosome-like bodies appear for the first time at the period of nuclear division, and gradually disappear with the formation of the daughter nuclei. Thus these structures are not permanent organs of the cell, but arise *de novo* at each mitosis to carry on the mechanism of nuclear division.

Formation of tetraspores

By normal cell division the disk cell divides into two portions, the upper portion becoming the tetraspore mother cell, while the lower portion becomes the stalk cell. The tetraspore mother cell in its growth assumes a clavate form, while its nucleus increases in size. At first the structure of the nucleus appears to be the same as that of the vegetative nucleus, but by the time the conceptacle has developed sufficiently to be recognized as such, the nucleus of the tetraspore mother cell enters upon the stage of synapsis. In *Corallina* the chromatin material is so scanty that a continuous spireme cannot be formed, but remains in two groups of small granules at the poles of the nucleus. When the synaptic period has passed, a centrosome-like body appears at each pole. In the metaphase a group of twenty-four bivalent chromosomes becomes arranged in an equatorial plate, and the paired chromosomes split longitudinally and separate into two groups. The first nuclear division, which is the heterotypic division, is soon followed by the second, or homotypic division. With the completion of the second division, there are formed four nuclei within the tetraspore mother cell, each of which possesses twenty-four univalent chromosomes. Later the tetraspore mother cell, by means of three cleavage furrows, becomes divided into four portions, each of which develops into a tetraspore containing one nucleus. The tetraspores then

escape from the conceptacle, float about freely in the water, and after becoming attached to a suitable substratum proceed to germinate.

Germination of tetraspores

The first nuclear division at the time of germination of the tetraspores shows twenty-four chromosomes. The same is true for the second and third divisions. With culture material the size of the plants obtained from germinating tetraspores was limited to thirteen cells. Throughout all these divisions there was no change as regards the number of chromosomes. The inference, therefore, is that such tetraspores, in nature, would give rise to sexual plants of normal size, possessing twenty-four chromosomes.

Formation of antheridium

The disk cell divides into two portions. The upper portion, which ultimately becomes the antheridium, is much smaller than the lower one, and is situated to one side of the latter. The two cells gradually become considerably elongated, the upper cell continuing to elongate until it finally attains a remarkable length. At the same time its nucleus divides, one daughter nucleus migrating to the extreme distal portion of the cell, while the other daughter nucleus remains in the lower portion. Just below the upper daughter nucleus a cell wall is formed, dividing the original upper cell into a very short terminal cell and a very long lower cell. The terminal cell becomes much enlarged and assumes a spherical form; the nucleus also enlarges greatly and occupies the larger portion of the cell. Thus the antheridium of *Corallina* is composed of a larger, spherical, terminal cell and a very much elongated, narrow, stalk cell. Later this spherical cell separates from the filiform stalk cell and functions as the spermatium. More than one antheridium may be formed from the same disk cell. The antheridial nuclei have constantly twenty-four chromosomes. The spermatium has a thin cell wall derived entirely from the mother cell, and when compared with other Florideae it is homologous with a unicellular antheridium. In 1911 SVEDELIUS, after having studied *Delesseria*, reported that the spermatium simply consists of the

naked protoplast discharged from the mother cell. I believe, however, that this would be disproved by a careful reinvestigation.

Formation of procarp

Each disk cell produces one carpogonial branch or procarp. The steps in the development of the procarp are as follows: The disk cell divides to form two cells, the upper one becoming the auxiliary cell and the lower one the stalk cell. The auxiliary cell then gives rise to a cell at one side of its exposed terminal portion, and then similarly to another cell at the other side. Thus two sister cells are produced from the auxiliary cell, situated side by side. Of these two cells, the first one formed has become greatly elongated by the time the second sister cell is formed. The nucleus of the older sister cell divides to form two nuclei; one nucleus remains in the enlarged basal region of the cell (carpogonium) and becomes the carpogonial nucleus, while the other one enters the hairlike upper portion of the cell (trichogyne) and functions as the trichogyne nucleus. The trichogyne is separated from the carpogonium by a constriction. The younger sister cell, which is usually provided with one nucleus, ceases to grow further at an early stage in its development, and simply remains as a non-functional structure beside the carpogonium formed by its older sister cell. Every one of the many disk cells, at the growing tips of the thallus branches, produces a procarp.

As just described, each procarp is composed of a stalk cell, auxiliary cell, carpogonium, and trichogyne, together with the small nonfunctional sister cell of the carpogonium. The structure of the procarp of *Corallina*, therefore, would seem to be simpler than that of other Florideae; yet in many Florideae the procarps are solitary, or, as in the case of *Ceramium*, two occur side by side. In *Corallina*, however, 60–70 or sometimes over 100 independent procarps occur in a group within the same conceptacle, and after fertilization, before the formation of the carpospores, they fuse with one another, resulting in the formation of one common structure.

Fertilization and formation of cystocarp

The trichogynes project above the surface of the conceptacle and are thus freely exposed to the sea water. A floating spermatium comes in contact with the apex of the trichogyne, adheres to

it, and discharges its contents into it. The trichogyne nucleus now begins to disintegrate. The spermatium nucleus proceeds downward, finally reaching the carpogonial nucleus, with which it fuses. At this time the auxiliary cell unites with the auxiliary cells of adjacent procarps, resulting in the formation of a large central cell within the conceptacle. The passage between this central cell and the carpogonium broadens. The sporophytic or fertilized carpogonial nucleus now passes into the large central cell. Since the sporophytic nuclei of all the procarps within the conceptacle migrate into this central cell, there are therefore over 100 sporophytic and also about the same number of gametophytic or auxiliary cell nuclei included in this common cytoplasm. The two kinds of nuclei found in the central cell differ as regards their structure. The sporophytic nuclei are usually large, rich in chromatin, and possess forty-eight chromosomes; the gametophytic nuclei are small, possess twenty-four chromosomes, and most of them gradually disintegrate.

Each sporophytic nucleus moves to the periphery of the central cell, where it divides to form two nuclei. One nucleus enters the cell which has been formed on the outer surface of the central cell, while the other nucleus remains inside the central cell. From the cell produced on the external surface of the central cell, a chain of cells is formed in basipetal sequence. These cells enlarge, become spherical, and when they have attained the size of tetraspores, gradually become constricted, separate, and finally escape from the conceptacle as carpospores.

Germination of carpospores

After the carpospores have escaped from the conceptacle, they begin to germinate within twenty-four hours. The first nuclear division is of the normal type and shows forty-eight chromosomes. The same is true of the second and third divisions. The sporelings continue to develop until the 17-celled stage is reached, all of the cell divisions being of the normal type and showing constantly forty-eight chromosomes.

Summary

1. The male and female plants of *Corallina* possess twenty-four chromosomes, while the tetrasporic plants have forty-eight chromosomes.

2. During the formation of tetraspores the forty-eight chromosomes become reduced to twenty-four. The tetraspores on germination show twenty-four chromosomes, and since twenty-four chromosomes appear in the vegetative mitoses of the sexual plants, the inference is that the latter arise from tetraspores.

3. The nuclei of the reproductive cells (spermatia and carpogonia) of the sexual plants possess twenty-four chromosomes. The sporophytic or fusion nucleus, as a result of fertilization, has forty-eight chromosomes. The sporophytic nuclei give rise by division to the carpospores, which also possess forty-eight chromosomes. The carpospores on germination show forty-eight chromosomes, and since forty-eight chromosomes appear in the vegetative mitoses of the tetrasporic plants, it is inferred that the tetrasporic plants originate from carpospores.

4. The male and female plants are gametophytic, while the tetrasporic plants are sporophytic. The sporophytic generation begins with the formation of the sporophytic or fusion nuclei, extends through the formation of the cystocarp and carpospores, and finally terminates with the formation of tetraspores on the tetrasporic plant. With the formation of the tetraspores, the gametophytic generation commences.

5. Thus *Corallina* is another clear example of the alternation of a sexual plant (gametophyte) with a tetrasporic plant (sporophyte), the cystocarp occurring as an early phase of the sporophytic generation.

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TOKYO, JAPAN

INTRA-OVARIAL FRUITS IN CARICA PAPAYA

H. F. Bergman

(WITH SIX FIGURES)

An unusually interesting teratological phenomenon came to notice recently when in cutting open a fruit of papaya (*Carica Papaya* L.) five small secondary fruits were found within the seed cavity. Externally the fruit containing them was in no way

FIG. 1.—Papaya fruit cut longitudinally, showing seeds and secondary fruits in position; one secondary fruit turned over to show production of seeds; $\times\frac{3}{4}$.

different from any other specimen to indicate the presence of the secondary fruits. These were attached near the basal end of the fruit, growing out from the placenta and replacing the seeds. In addition to the four conspicuous fruits there was found also one very much smaller. Fig. 1 shows four of the inclosed fruits in situ. Only the style and stigma of the fourth, the smallest fruit, is visible.

Four of the five fruits consisted of an ovary surmounted by a sessile stigma. The ovary was not completely developed, in any case only a single carpel probably being represented. Each of the four larger inclosed fruits produced seeds. This may be seen from the figure, one of the fruits being placed to one side and turned over to show the incomplete development and the production of ovules. The stigmas, instead of being flattened and laciniate, as in normal fruits, were capitate, considerably swollen, spongy, and with tuberculate surface. The smallest fruit has a very small ovary, without ovules, the capitate stigma being borne on an elongated style (fig. 2). The inclosed fruits were yellow, being somewhat paler than normal fruits.

FIG. 2.—Sketch of small secondary fruit only partly visible in fig. 1; natural size.

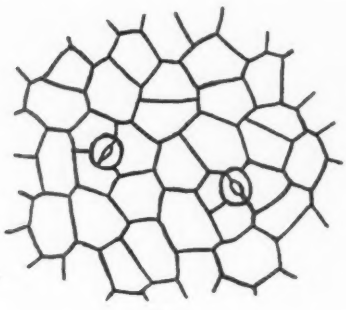


FIG. 3

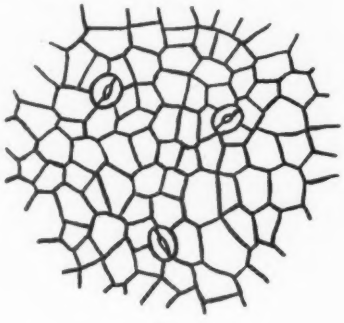


FIG. 4

FIGS. 3, 4.—Fig. 3, portion of epidermis of secondary fruit showing stomata; ×160; fig. 4, portion of epidermis of normal fruit showing stomata; ×160.

A microscopic examination of the epidermis of these fruits (fig. 3) showed it to be made up of cells similar in shape but somewhat larger than those of the epidermis of normal fruits (fig. 4). This similarity extended even to the presence of stomata. The guard cells were without chloroplasts. The only evident external difference in the epidermis of the inclosed fruits from that of normal fruits was in the absence of the coating of wax which the latter possesses in a marked degree. In cross-section the structure of the inclosed fruits resembles closely that of normal fruits, the

epidermis being thinner in the former. This and the absence of wax is probably due to the fact that they were not exposed. In all respects the seeds resemble those produced by a normal fruit. The embryo was found to be present in the several seeds examined, and to all appearances, so far as could be ascertained with a hand lens, was of normal form and size.

Some two or three months after finding these specimens, another set of intra-ovarial fruits of papaya was supplied to the writer through the kindness of Dr. L. O. KUNKEL, of the Hawaiian

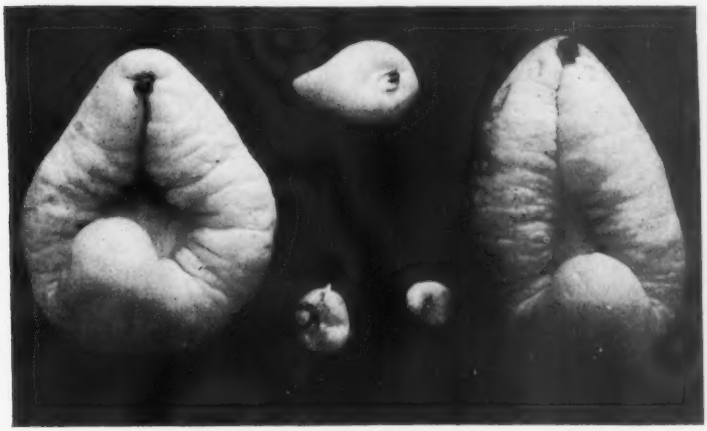


FIG. 5.—Secondary fruits from seed cavity of papaya; slightly reduced

Sugar Planters' Experiment Station. These are shown in fig. 5. Only two of them are comparable in form and size to those shown in fig. 1. These two were rough surfaced, as may be seen from the illustration. The lower one of the three middle specimens shown in fig. 5 differed in being turbinate and smooth surfaced. In cross-section it was circular, without a seed cavity, but having a single vascular bundle near the center. All five fruits in this case were a very light cream color. No matured seeds were found, although the two larger ones had a placental surface with a few rudimentary ovules. The styles of the larger ones were filiform, tipped by a very small capitate stigma. An examination of the epidermis of

three of the five specimens showed it to be similar to that figured for the other specimens (fig. 3).

These intra-ovarial fruits, although they occur on the placentae, cannot with certainty be regarded as metamorphosed ovules. Instead it is more probable that they were produced from buds which developed adventitiously in places which would normally be occupied by ovules. The occurrence of adventitious formations within the ovary replacing ovules has been observed by several botanists. MASTERS[1] figures and describes a silique of *Cheiranthus*

FIG. 6.—Portion of papaya fruit showing secondary pistil as proliferation of stem axis; ×1.25.

Cheiri which contained an adventitious silique, replacing an ovule, within an ordinary silique, and also a grape which had another grape inside in the place of a seed. He also quotes and shows figures of a case described by BERKELEY[2] of a carnation in which the placentae bore both ovules and carpels. In this case transitional forms between the normal ovules and their carpellary transformations were found. Some of the carpels derived from ovules produced secondary ovules. MASTERS states that in the carnation

[1] MASTERS, M. T., Vegetable teratology. London. 1869.

[2] BERKELEY, M. J., Gardener's Chronicle, September 28, 1850 (p. 612).

specimens described by BERKELEY "the nucleus of the ovule was not developed." No transitional forms between ovules and secondary fruits such as were described by BERKELEY in the carnation were found in these papaya specimens.

The formation of secondary fruits within the ovary is evidently not uncommon in the papaya, and has been observed by many persons. It is said that in some instances the intra-ovarial fruits are exact models in miniature of the normal fruits. No information was obtained as to whether or not such fruits have a seed cavity with ovules or seeds.

An instance of the formation, in a different manner, of a secondary pistil within the seed cavity has also been observed. In this case the secondary fruit, instead of arising from the placenta in place of an ovule, occurred as a proliferation of the vascular axis which extends from the pedicel through the pericarp (fig. 6). The form of the pistil is not representative of the normal form in pistillate flowers, but is of the type that is to be found in a petunia or other similar flower. On cutting the ovary transversely it was found that no seed cavity was present. A single vascular strand was located in the center.

MASTERS refers to intra-carpellary prolification and states that "it occurs most frequently in plants having a free central placenta, though it is not confined to them, as it is recorded among Borragineae." No instance is cited, however, of a proliferation of the form here described.

UNIVERSITY OF HAWAII
HONOLULU

LEAVES OF CERTAIN AMARYLLIDS[1]

AGNES ARBER

(WITH EIGHT FIGURES)

In a previous memoir[2] attention has been drawn to the existence of leaves with a phyllodic type of anatomy among the Amaryllidaceae. In the present paper it is proposed to discuss certain special cases drawn from this family.

Leaf-anatomy of Narcissus

The foliage leaves of *Narcissus* consist typically of a linear limb (fig. 1, *l*) and a short sheathing base (*b*). In the very young leaves the sheath is relatively the more conspicuous organ, while the limb is scarcely developed. This relation is shown in fig. 2, drawn from a leaf which slightly exceeded 1 mm. in length. In *N. Tazetta* L. limbless sheathing leaves occur, in addition to foliage leaves in which both sheath and limb are developed. An examination has been made of the anatomy of the limb in the following species, representing the various sections of the genus:

SUBGENUS EUNARCISSUS

Section AJAX.—*N. Pseudo-narcissus* L.

Section GANYMEDES.—*N. triandrus* L.

Section QUELTIA.—*N. incomparabilis* Mill., *N. Jonquilla* L., *N. juncifolius* Req., *N. reflexus* Lois.

Section GENUINI.—*N. biflorus* Curt., *N. poeticus* L.

Section HERMIONE.—*N. Tazetta* L.

SUBGENUS CORBULARIA

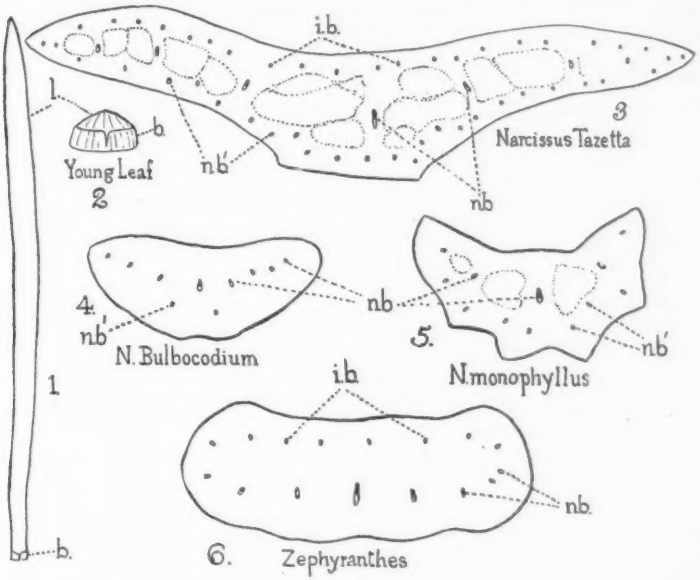
N. Bulbocodium L., *N. monophyllus* T. Moore.

Anatomy of the type interpreted as phyllodic[2] has been found in *Narcissus Pseudo-narcissus, N. triandrus, N. incomparabilis,*

[1] This paper represents part of the work carried out during the tenure of a Keddey Fletcher-Warr Studentship of the University of London.

[2] ARBER, AGNES, The phyllode theory of the monocotyledonous leaf, with special reference to anatomical evidence. Ann. Botany **32**:465–501. 1918.

N. Jonquilla, *N. biflorus*, *N. poeticus*, and *N. Tazetta;* that is, in at least one species from each of the five sections of the subgenus *Eunarcissus*. The leaf of *N. Tazetta* may be taken as a type (fig. 3). In this species there is a single series of main bundles lying roughly midway between the upper and lower epidermis (*nb*), and a series of smaller bundles lying near the lower epidermis (*nb'*). These

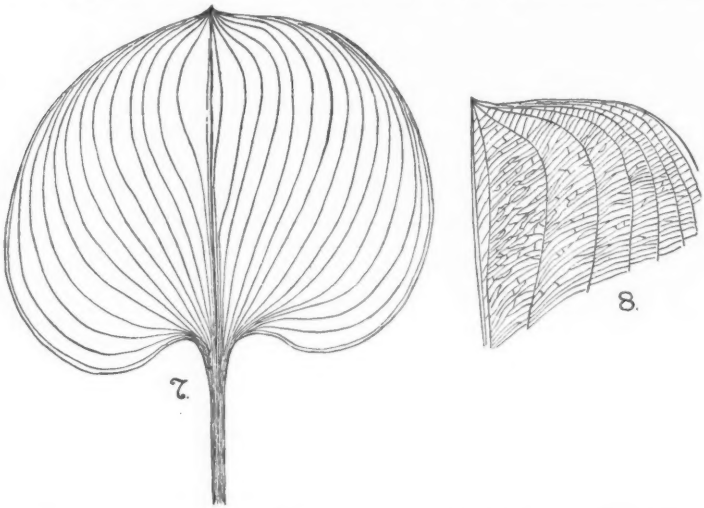


FIGS. 1–6.—Fig. 1, *Narcissus* sp. (garden var.): leaf showing relation of sheath to limb at maturity, ×0.5; fig. 2, *Narcissus* sp. (garden var.): young leaf, slightly more than 1 mm. long showing predominance of sheath; fig. 3, *N. Tazetta* L.: transverse section of limb of leaf, ×14; fig. 4, *N. Bulbocodium* L.: transverse section of limb of leaf, ×23; fig. 5, *N. monophyllus*, T. Moore.: transverse section of limb of leaf, ×23; fig. 6, *Zephyranthes candida* Herb.: transverse section of limb of leaf, ×14; *l*, limb; *b*, sheath; *nb* and *nb'*, series of normally orientated bundles; *ib*, series of inverted bundles (xylem in black, phloem in white, and outlines of lacunae in dotted line).

strands are all normally placed with the xylem upward. In addition there is a series of inverted bundles (*ib*) toward the upper surface. *N. triandrus* has a slender grooved leaf with peripheral bundles, whose xylem faces inward. The leaf anatomy of *N. Tazetta* and

N. triandrus may be compared with that of other Amaryllids in which inverted bundles occur toward the upper surface, as *Zephyranthes candida* Herb. (*Amaryllis nivea* Schult.) (fig. 6). In these cases the structure is interpreted as indicating that the limb is of a petiolar nature.

The only plants belonging to the subgenus *Eunarcissus* in which non-phyllodic anatomy has been found are *N. juncifolius* Req. and *N. reflexus* Lois.; in these all the bundles are normally orientated. This type of structure, however, although apparently rare in



FIGS. 7, 8.—*Eurycles sylvestris* Salisb.: fig. 7, leaf, petiole incompletely shown, ×0.25; fig. 8, small part of righthand side of leaf near apex, ×0.5.

Eunarcissus, is characteristic for the subgenus *Corbularia*. In both *N. Bulbocodium* (fig. 4) and *N. monophyllus* (fig. 5) only two series of bundles are found, both of which are normally orientated; the inverted series toward the ventral surface is absent.

The interest of the leaf anatomy of *Narcissus*, from the standpoint of the phyllode theory, lies in the fact that within the same genus there are examples of phyllodic anatomy (fig. 3), and of a reduced form of anatomy (figs. 4, 5) in which the loss of the inverted bundles results in a structure to some extent simulating that of a

true lamina. That the anatomical type shown in figs. 4 and 5 is indeed a reduction from that shown in fig. 3, and that the series should not be read in the reverse direction, are suggested by the general morphology of the subgenus *Corbularia*. The extreme corona development and the tendency to zygomorphy in the hoop-petticoat daffodil, as CHURCH[1] has suggested, point to its being a more advanced and specialized type than the various forms of *Eunarcissus*.

Pseudo-lamina of Eurycles

The leaf of *Eurycles sylvestris* Salisb. furnishes a very characteristic example of what has elsewhere[2] been described as the "pseudo-lamina" of the monocotyledon. The blade (fig. 7) is large. A herbarium specimen was measured in which it was 19 cm. long by 25.5 cm. wide. Fig. 7 shows that the primary skeletal system of this pseudo-lamina may well be interpreted as originating by the separation of the veins of the distal end of the petiole. The secondary and tertiary venation is also of interest from this point of view (fig. 8). A very large number of the secondary veins are unbranched and unconnected, and it is noticeable that the tertiary veins are extremely irregular; some pass from one secondary vein to another, some go from one secondary vein to a primary; while others leave a secondary vein, form a loop, and return to the vein whence they arose. The anomalous character of this venation seems not inconsistent with the view that the blade of the monocotyledon is an organ which is still at the experimental stage of its evolution from an expanded petiole.

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[3] CHURCH, A. H., Types of floral mechanism. Part I. Oxford. 1908.

A HOMOSPOROUS AMERICAN LEPIDOSTROBUS

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY **283**

JOHN M. COULTER AND W. J. G. LAND

Strobili of *Lepidodendron* so perfectly preserved that they can be sectioned and their minutest structures studied are common in European coalfields. Many of these strobili show heterospory, the megasporangia being at the base of the strobilus, the microsporangia above. The extensive literature of the subject is fully cited by SCOTT[1] and SEWARD,[2] and need not be repeated here. The extensive American coalfields, with but two exceptions, have yielded nothing but casts as yet. Perhaps the reason for this seeming scarcity of petrified material is that it has not been looked for carefully by competent observers.

In 1911 there came to this laboratory from Professor JOHN L. TILTON, of Simpson College, Indianola, Iowa, a well preserved fragment of a strobilus from the coalfields of Warren County, Iowa. This fragment, from above the middle of the strobilus, showed small spores, but of course nothing concerning heterospory could be determined. This specimen, the first American *Lepidostrobus* to be sectioned, was fully described by COULTER and LAND.[3] TILTON reexamined very carefully the place where the first fragment was found, and discovered several fragments of cones in a very good state of preservation, and evidently the same species as the first fragment. These he kindly sent to this laboratory. A few fairly well preserved stems of *Lepidodendron* also have been received from the coalfields of western Indiana. No cones were found, but it is evident that these fields will repay intelligent search.

Among the later fragments obtained from TILTON were four pieces which matched perfectly, showing clearly that they were

[1] SCOTT, D. H., Studies in fossil botany. London. 1909.

[2] SEWARD, A. C., Fossil plants. Cambridge. 1910.

[3] COULTER, J. M., and LAND, W. J. G., An American *Lepidostrobus*. BOT. GAZ. 51:449–453. *figs. 23*. 1911.

from the same strobilus, the tip being the only part missing. The restored strobilus was 22 cm. long and 5 cm. in diameter at the base. The structures were well preserved, with the exception of the axis, which is replaced by calcite and pyrites. The strobilus is mature; the sporangia have all opened and are empty excepting here and there a few spores. Enough sections were made to show its character, from the base to the broken tip, the general condition of the strobilus being almost exactly identical with that of the fragment described by COULTER and LAND. There is no appreciable difference in size of any of the spores, both those in the basal sporangia and in the sporangia near the apex averaging 27 μ in diameter. It seems probable, therefore, that this particular species of *Lepidostrobus* is homosporous, although it is possible that the spores found in the basal sporangia entered through the dehiscence slits. It would seem almost impossible that, in such a well preserved and compact strobilus, all of the megaspores, if there were any, could have escaped. The real solution of the problem lies in the finding of younger strobili which have not yet shed any spores. Negative evidence, however probable, is never conclusive; but the evidence in the present case is so strong that it seems safe to infer that this species of *Lepidostrobus* is homosporous.

The form genus *Lepidostrobus* was originally established to include all of the strobili of *Lepidodendron*. Later it was found that all such strobili could not be included, even in a form genus, so that "true" *Lepidostrobus* is restricted to those strobili of *Lepidodendron* characterized by "the great radial elongation of the sporangium, and its attachment by a long and narrow insertion to the upper surface of the sporophyll-pedicel throughout its length."[4] The chief interest in connection with these strobili is the question of heterospory. If heterospory has been attained by all these forms, the origin of the homosporous Lycopodiales is left in the region of the unknown. Certain species of *Lepidostrobus* are known to be heterosporous, and all of them are suspected. In one well preserved specimen the microsporangia occur in the upper part of the strobilus and the megasporangia in the lower part, as in certain species of *Selaginella*. The inference has been that

[4] SCOTT, D. H., Studies in fossil botany. London. 1909.

all the species of *Lepidostrobus* have probably reached the level of *Selaginella* in this feature, or, in other words, that *Selaginella* is the modern representative of this group. In the *Lepidostrobus* form referred to, the microspores are 20μ in diameter, and the megaspores 800μ, so that there is no question as to the great differentiation in size. The discovery of a *Lepidostrobus*, therefore, which is evidently homosporous is worthy of record and consideration. If these old strobili included both homosporous and heterosporous forms, the history of the modern Lycopodiales would become simpler. It would also emphasize the independent origin of heterospory in lines which could by no possibility be related.

UNIVERSITY OF CHICAGO

CURRENT LITERATURE

BOOK REVIEWS

A textbook of botany

FRITCH and SALISBURY[1] have prepared a sequel to their *Introduction to the study of plants*. In the more elementary volume the microscopic details were omitted, and therefore the present volume supplies these details for those who wish to know more about plants. Although the anatomical structure and reproduction of plants are the main subjects, the authors have included enough physiology and ecology to relate structure to function, and to indicate the responses of structures. In connection with reproduction, also, there is a supplementary chapter on heredity and evolution. It is interesting to note that the authors have abandoned the old method of types, and have treated groups as a whole, which certainly results in a better conception of the organization of the plant kingdom. They have also developed the economic contact when appropriate, stating that the purpose is "to combat the frequent ignorance of botanical students with respect to the economic aspects of their subject." This tendency is developing strongly in all the sciences, and is to be commended as developing a more general appreciation of science, and also as helping to do away with the old artificial distinction between "pure" and "applied" science.

The first part of the volume, devoted to anatomy, is an excellent general presentation of the subject, and one that is needed. There has been a tendency in the more recent texts to deal chiefly with the anatomy of the reproductive structures, with perhaps some supplementary information in reference to vascular anatomy, omitting the numerous other structures that enter into the structure of plants. In the second part, the life histories of the great groups are considered in evolutionary sequence, relating the facts to conditions of living and to future progress.

The volume is well illustrated, and should prove to be a valuable addition to the botanical texts for English students.—J. M. C.

Principes de botanique

It is a gratification to botanists, long familiar with the work of CHODAT, to greet the third edition of his well known textbook.[2] The first edition

[1] FRITCH, F. E., and SALISBURY, E. J., An introduction to the structure and reproduction of plants. 8vo. pp. viii+458. *figs. 230*. London: G. Bell & Sons. 1920.

[2] CHODAT, R., Principes de botanique. Troisième édition, revue et augmentée. pp. x+878. *figs. 921*. Genève: Édition Atar. 1921.

appeared in 1907, and the third was ready in 1914, but its publication was prevented by the war and the unfavorable conditions of printing. The author has included the more important recent results of investigation, presented in his very attractive style, and with abundant illustrations.

The organization of the subject is peculiar to CHODAT, and therefore the volume has a flavor of its own. The four general divisions of the subject are as follows: "Physiologie générale," "La cellule, les tissus," "Physiologie spéciale," and "Génétique." The chapter topics under this general organization are often unusual. For example, practically everything usually treated under morphology, with the exception of anatomy, is presented under "special physiology," the evident suggestion being that structures are only significant in connection with their functions.

It is unusual for a book of nearly 900 pages to contain only ten chapters, and the subjects are suggestive of the organization. They are as follows: under general physiology, "Constitution de la matière vivante" and "Captation et transformation de l'énergie"; under the cell and tissues, "La cellule," "Organogénie," and "Anatomie"; under special physiology, "Fonctions de circulation et d'élaboration," "Fonctions de relation," and "Reproduction"; under genetics, "Variations, hérédité," and "Conclusion" (theories of the origin of species). The volume closes with a brief classification of plants.—J. M. C.

MINOR NOTICES

Dictionary of botanical equivalents.—ARTSCHWAGER and SMILEY[3] have prepared a very convenient dictionary which gives accurate translations of technical terms which are not usually found in ordinary dictionaries. All technical terms have been omitted when the English equivalent would be practically a repetition of French and German terms of Latin or Greek origin. As the compilers state, it is "a practical hand-book, accurate within the limits set for it." The publishers have also provided interleaved blank pages, so that users of the volume may amplify the list. It will certainly prove a very convenient volume for the reader of French and German botanical literature, both in saving time and in insuring accuracy.—J. M. C.

NOTES FOR STUDENTS

Chlorophyll inheritance.—Considerable interest has always been focussed upon reported cases of non-Mendelian inheritance. For the most part these have later been explained satisfactorily on a Mendelian basis, so that at the present time the only clearly recognized cases of non-Mendelian inheritance

[3] ARTSCHWAGER, ERNST, and SMILEY, EDWINA W., Dictionary of botanical equivalents (French-English, German-English). 16mo. pp. ii+137. Baltimore: Williams & Wilkins Co. 1920.

are certain types of chlorophyll inheritance. WINGE[4] makes a hopeful attempt to classify all known cases of chlorophyll inheritance according to the following scheme:

I. The characters are situated in the nucleus and show Mendelian segregation, self-colored green usually being dominant. To this class belong the well known *alniba*, *citrina*, *chlorina*, *variegata*, and *albomarginata* forms of *Melandrium*, *Antirrhinum*, *Pelargonium*, *Mirabilis*, *Urtica*, *Aquilegia*, *Lunaria* (CORRENS, BAUR, and others). The most complex case on record is one recently solved by LINDSTROM[5] in which the F_2 of a trihybrid gives the remarkable ratio of 36 green:9 virescent-white:7 yellow:12 white.

II. The characters are situated elsewhere than in the nucleus and do not show Mendelian inheritance. This class is further split up in the following interesting way: (*a*) The characters are transmitted by the plastids themselves. In this case plants which are endowed with both green and colorless plastids may, through the uneven distribution of plastids of the two types at cell division, give rise to pure green and pure white areas, really a "somatic segregation." Such areas, through seed, will breed true to their local character. There is one known case, the "mosaic" *Pelargonium zonale* of BAUR, in which plastids evidently accompany the male nucleus at fertilization, for here inheritance is bi-parental. In all other known cases no plastids accompany the male nucleus, and inheritance is strictly maternal. In this last group we find the *albomaculata* forms of *Mirabilis* (CORRENS), *Antirrhinum* (BAUR), and *Primula* (GREGORY).

(*b*) The characters are situated in the cytoplasm. In this case no thoroughgoing "somatic segregation" is possible. A "hybrid" plant, combining the character for normal chlorophyll development with the alternative character for chlorophyll deficiency, will have these characters well diffused and intermingled through the cytoplasm. At cell division there may result a somewhat uneven distribution of these effective elements in the cytoplasm, resulting in relatively "lighter" and "darker" areas on the plant. This process of "dilution," however, has never been known completely to "purify out" either of the elements. Pure albinos or pure green individuals are never produced by these "hybrids." Here too we find in one case, the *albomaculata* form of *Capsella* (IKENO), the male nucleus seems to be accompanied by some cytoplasm, since the chlorophyll inheritance is bi-parental. In the only other case on record, the *albomaculata* of *Humulus* (WINGE), the male evidently contributes no cytoplasm, for inheritance is strictly maternal.

This classification seems fairly satisfactory, but it involves some fundamentally different conceptions from those of CORRENS and BAUR. Probably

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[4] WINGE, O., On the non-Mendelian inheritance in variegated plants. Compt. Rend. Lab. Carlsberg **34**:1–20. *figs. 4.* 1919.

[5] LINDSTROM, E. W., Concerning the inheritance of green and yellow pigments in maize seedlings. Genetics **6**:91–110. 1921.

the most significant fact, and one about which there can no longer be any doubt, is that chlorophyll inheritance is sometimes Mendelian and sometimes non-Mendelian. Naturally this suggests that other types of characters also may be, at least in some cases, non-Mendelian in inheritance.—M. C. COULTER.

Plagiotropic shore plants.—From the results of experiments carried on largely with *Atriplex prostratum*, TURESSON[6] reached the conclusion that the external factor causing prostrate growth is intense illumination, but that the growth movements are really geotropic in their nature. Emphasis is placed upon the fact that there are apparently two distinct sorts of plagiotropy, the one resulting from congenital habits of growth, and the other from response to environmental conditions. At times a single species, such as the one under experiment, will prove to consist of two such forms.—GEO. D. FULLER.

Haustoria of Meliola.—Miss DOIDGE,[7] in continuation of her studies of South African Perisporiaceae, has examined the haustoria of *Meliola*, whose species occur chiefly on leaves and shoots of forest trees and shrubs. She determined that the species are true parasites, sending haustoria into the cells of the host, penetrating the cuticle and in some cases sclerenchyma cells. The species differ in the length and character of the penetrating filament.—J. M. C.

North American flora.—Part 2 of volume 32 includes a continuation of Rubiaceae by STANDLEY. The preceding part included 20 genera, to which the present part adds 41 more. Much the largest genera are *Bouvardia* with 30 species (12 new) and *Exostema* with 26 species (5 new). The remaining 5 new species are distributed among the smaller genera.—J. M. C.

Vegetation of Paraguay.—Continuing his report on the scientific results of a botanical expedition to Paraguay, CHODAT[8] discusses the Apocynoceae, Urticales, and Araceae observed and collected. A number of new species are described, and rather extensive notes are made on distribution and ecology.—GEO. D. FULLER.

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[6] TURESSON, GÖTE., The cause of plagiotropy in maritime shore plants. Lunds Univ. Arsskrift. N.F. Avd. 2. **16**: no. 2. pp. 32. *pls.* 2. 1919.

[7] DOIDGE, ETHEL M., South African Perisporiaceae. VI. The haustoria of the genera *Meliola* and *Irene*. Trans. Roy. Soc. S. Africa **9**:117–127. *figs.* 7. 1921.

[8] CHODAT, R., La végétation du Paraguay. Fasc. 3. Geneva. pp. 291–379. *figs.* 53. 1920.

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